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Indian Standard

GUIDE TO THE USE OF PIEZOELECTRIC FILTERS

PART II PIEZOELECTRIC CERAMIC FILTERS

(First Reprint December 1996)

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NEW DELHI 110002

Gr 6 *November* 1975

Indian Standard
GUIDE TO THE USE OF PIEZOELECTRIC FILTERS
PART II PIEZOELECTRIC CERAMIC FILTERS

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Sectional Committee, ETDC 51

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Indian Standard

GUIDE TO THE USE OF PIEZOELECTRIC FILTERS

PART II PIEZOELECTRIC CERAMIC FILTERS

0. FOREWORD

0.1 This Indian Standard (Part II) was adopted by the Indian Standards Institution on 30 April 1975, after the draft finalized by the Piezoelectric Crystal for Frequency Control and Selection Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 Electrical filters are widely used in communication, telemetry, navigation and measurement applications. In many cases, the amplification and the filtering are combined as in the case of interstage transformers between active devices such as tubes, or solidstate devices. Recent demands for sharper selectivity, flatter pass-band characteristics, higher stop band attenuation, higher stability and lower ageing have resulted in increasing use of filters as independent units separated from amplifiers. The advent of integrated circuits has accelerated this trend.

0.3 The qualities of filter are mainly governed by the characteristics of the resonant elements used in the filter. Piezoelectric resonators are superior to conventional LC resonant circuits in such characteristics as the quality factor (Q), temperature characteristics, ageing rate, size and weight. Hence, a wide variety of piezoelectric filters is now available commercially.

0.4 There are two main types of piezoelectric filters, namely, quartz crystal filter and ceramic filter. There are certain similarities as well as dissimilarities between these two types of filters. Two standards have been prepared in response to a generally expressed desire on the part of both users and manufacturers for a guide to the use of piezoelectric filters, so that the filter may be used to its best advantage — one [IS : 7410 (Part I)-1974*] relates to quartz crystal filters and the second (this standard) relates to ceramic filters.

0.5 With the progress in research and development of stable piezoelectric ceramic materials, a new rather promising field has appeared in designing high quality, miniature and economical filters using piezoelectric ceramic resonators.

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*Guide to the use of the piezoelectric filters: Part I Quartz crystal filters.

0.6 The availability of ceramic resonators with a high coupling factor, high quality factor and a satisfactory stability has permitted design of ceramic filters which can be used as alternatives to LC filters, mechanical filters and for new applications.

0.7 It is not the object of this standard to explain theory, nor to attempt to cover all the eventualities which may arise in practical circumstances. This guide draws attention to some of the fundamental questions which should be considered by the user before he places an order for a filter for a new application. Such a procedure will be the user's insurance against unsatisfactory performance.

0.8 While preparing this standard, assistance has been derived from IEC Pub 368B-1975 'Second supplement to Pub 368-1971 Piezoelectric filters', issued by the International Electrotechnical Commission.

1. SCOPE

1.1 This standard (Part II) deals with the use of piezoelectric ceramic filters to ensure their optimum performance.

1.2 The scope of this standard is limited to passive band-pass filters operating over the frequency range from a few kHz to more than 10 MHz which are commercially available as separate and independent units. Filters, which are integrated into a larger system, are not considered here. Filters considered in this standard are limited to two-port filters using passive linear elements.

2. TERMINOLOGY

2.1 For the purpose of this standard, the terms and definitions given in IS : 1885 (Part XXXIII)-1972* shall apply.

3. GENERAL

3.1 Piezoelectric ceramic filters (hereafter referred to as 'ceramic filters') are at present widely used in communication (in I.F. amplifiers of communication receivers), in equipment for forming a set of reference frequencies and also in telemetry and measurement application, as well as in the I.F. amplifiers of broadcast receivers. Although specifications for these filters are very diverse, many of the above needs may be served by a few standard types of ceramic filters.

3.2 Standard article sheets or data sheets issued by the manufacturer will define the available combinations of reference frequency, pass bandwidth, ripple, shape factor, terminating impedance, etc. These sheets are compiled to include a wide range of piezoelectric ceramic filters with standardized performances. It should be emphasized that the user should, wherever possible, select his ceramic filters from these sheets, when available, even if it may lead to making small modifications to his circuit to enable standard filters to be used. This is especially so in the selection of reference frequency.

---

*Electrotechnical vocabulary: Part XXXIII Piezoelectric filters.

3.3 In contrast to conventional LC filters and in comparison with crystal filters, ceramic filters offer substantial advantages in design and production costs, when their reference frequencies are limited to a few narrow frequency ranges. Hence an order which does not specify one of the more commonly used reference frequencies may be uneconomical.

3.4 It should be understood, that standardization is not a fixed, but rather a continuing process. As new requirements arise, new article sheets will be produced to meet these requirements, after careful consideration.

4. TECHNICAL INTRODUCTION

4.1 It is of prime interest to a user that the filter characteristics satisfy a particular specification. The selection of internal filter and resonator networks to meet that specification should be at the option of the manufacturer.

4.2 The amplitude *versus* frequency characteristics of a filter are usually expressed in terms of transducer attenuation as a function of frequency, as shown in Fig. 1. A standard method for measuring transducer attenuation is described in **8**. In some applications, such characteristics as transient response or group delay are more important than transducer attenuation. But these special characteristics are not considered here.

4.3 Transducer attenuation characteristics are further specified by reference frequency, minimum transducer attenuation, pass-band ripple and shape factor. The specification is to be satisfied between the lowest and the highest temperature of the specified operating temperature range. This condition shall also be satisfied before and after the environmental tests. In some cases, particularly for filters for broadcast receivers, maximum variation of characteristics over a given temperature range may be specified.

5. PIEZOELECTRIC CERAMIC RESONATORS FOR FILTERS

5.1 A brief description of ceramic resonators is included here, so that a user may understand the feasibility and the limitation in the design of ceramic filters due to the characteristics of resonators. In a conventional filter, inductors and capacitors are used as reactive elements. Inevitable dissipations associated with the components yield two-fold effects on filter characteristics. Firstly, the transducer attenuation becomes finite instead of zero in the pass band. Secondly and more serious, the sharpness of the attenuation characteristic near the cut-off frequency may be spoiled. The second effect mostly depends on the *Q* of components, whereas the first depends on, among other things, absolute values of dissipation.

5.2 A ceramic resonator is equivalent to a combination of reactive elements with a quality factor (*Q*) which is several times better than the *Q* of conventional inductors. Ceramic filters for equal relative bandwidth have transducer attenuation and shape factor between that of quartz and LC filters. Figure 2 shows a typical comparison of a ceramic filter with a conventional LC and a quartz crystal filter which are designed to have similar pass bands. It can be seen from the drawing that performance intermediate between quartz crystal filters and LC filters is achieved by the ceramic filters. The main advantages of using the ceramic resonators in a filter, however, are in obtaining much smaller size and lighter weight.

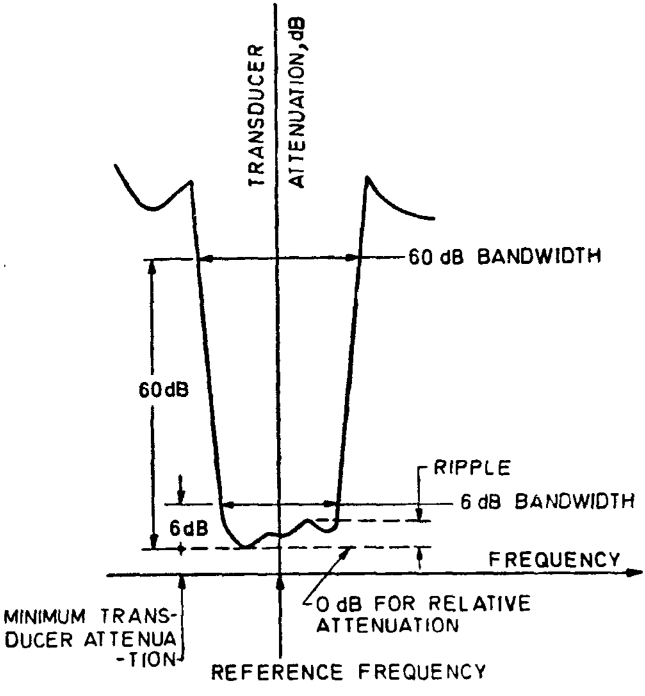

TRANSDUCER ATTENUATION, dB
60 dB BANDWIDTH
60dB
RIPPLE
6 dB BANDWIDTH
6dB
FREQUENCY
0 dB FOR RELATIVE ATTENUATION
MINIMUM TRANSDUCER ATTENUA-TION
REFERENCE FREQUENCY

FIG. 1 TRANSDUCER ATTENUATION CHAARCTERISTICS OF A FILTER

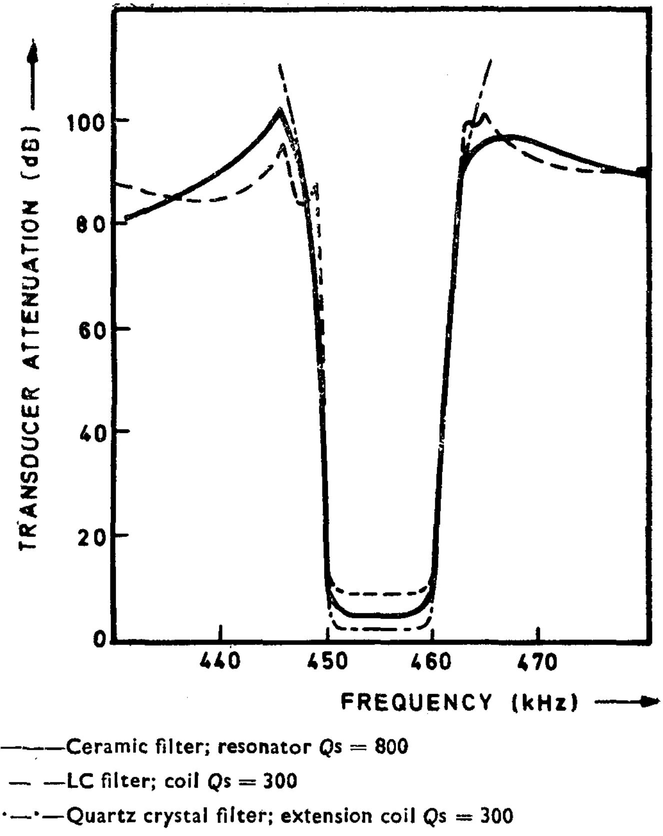
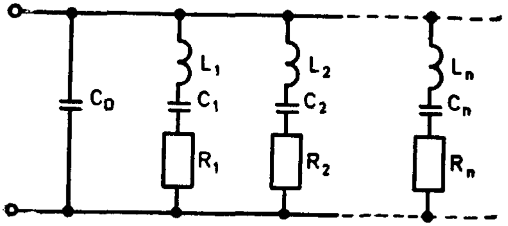
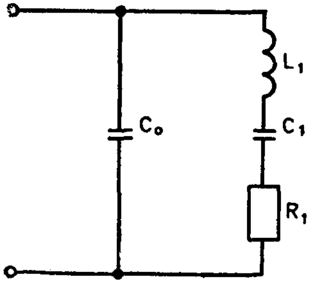


FIG. 2 COMPARISON OF CHARACTERISTICS OF A TYPICAL CERAMIC FILTER, LC FILTER AND A QUARTZ CRYSTAL FILTER, WITH THE SAME NUMBER OF RESONANT CIRCUITS

5.3 Electrical characteristics of a ceramic resonator used in a filter may be represented by the equivalent circuit shown in Fig. 3A. It consists of a capacitance C_D shunted by a number of parallel arms, consisting of equivalent motional inductance, capacitance and resistance in series, each of the arms having a resonance at definite frequencies. In the very vicinity of a resonance, a simplified equivalent circuit shown in Fig. 3B, which consists of a parallel capacitance C_0 and only one motional arm, may be used. The capacitance C_0, however, is frequency dependent, because not only the capacitance C_D but also the effect of other motional arms is included. Hence the simplified equivalent circuit may not be accurate enough to represent such characteristics of a resonator at antiresonance.



3A Circuit Valid for a Wide Range of Frequencies



3B Simplified Circuit Valid Only for the Immediate Vicinity of a Resonance

Formulae valid for every resonant circuit:

$$f_s = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

$$Q_m = \frac{2\pi f_s L_s}{R_1}$$

$$B_s = \frac{f_p - f_s}{f_s}$$

FIG. 3 EQUIVALENT CIRCUITS FOR A CERAMIC RESONATOR

5.4 Other convenient parameters for describing characteristics of a ceramic resonator are the series resonance frequency f_s, the parallel resonance frequency f_p, the mechanical quality factor Q_m and the relative frequency spacing B_s. Their general relationships with equivalent circuit parameters valid for every resonant circuit are also given in Fig. 3. The expression for f_p, however, is omitted, because of its complexity.

5.5 The quality factor and frequency stability of ceramic resonators limit the minimum pass bandwidth available in a ceramic filter, whereas the relative frequency spacing governs the maximum available pass bandwidth. For example, the maximum fractional bandwidth available is smaller than B_s for a ladder filter consisting of ceramic resonators and capacitors and smaller than B_s or $2B_s$ for a lattice filter.

5.6 Because a ceramic resonator utilizes a distributed mechanical structure there are numerous modes of vibration other than the main mode, intended for use in a filter. These modes occur sometimes in the vicinity of the main mode and disturb the filter characteristics. Such unwanted modes might be suppressed below a certain level or shifted to unimportant frequencies, but this might be difficult to achieve in filters having a wide pass band. For suppressing unwanted responses it is necessary to choose carefully the configuration, linear dimensions of resonators, shape of electrodes, mounting, etc. Linear dimensions should be so chosen that unwanted modes of vibrations will not fall into the relevant frequency range. With a ceramic resonator for a filter it is further required that all the reactance parameters are to be specified in a design. So far as the latter depend also on the resonator dimensions, the shape and location of electrodes, limitations are imposed on the range of feasible parameters for every particular frequency, the limits, being less severe than those applicable to a quartz filter resonator.

5.7 The range of available equivalent inductances at a particular frequency for radial mode resonators is about 8 : 1 and for high frequency resonators with thickness modes this may exceed 3 : 1. This imposes strict limitations on the design of ceramic filters.

5.8 Ceramic resonators differ from the crystal units by large values of the relative resonance spacing which can amount up to 15 percent in the case of lead streonate-lead titanate modifications. As a result of this feature, piezoelectric filters using ceramic resonators can be designed with a sufficiently large bandwidth without using added elements. The second advantage of ceramic resonators which allows the design of ladder filter networks consisting of resonators only, is the large values of shunt capacitance. The small value of equivalent inductances of ceramic resonators (mH units) is also an advantage when using them in filters for solidstate circuits, because the characteristic resistance value of filters is obtained such as to go well with the output resistance of the circuits.

5.9 A resonator with more than one pair of electrodes is sometimes used in a filter, for example, a ring and dot resonator is used for interstage coupling in I.F. filters of radio sets. There are also resonators utilizing more than one main mode of vibration.

5.10 Such coupled-mode filters offer some advantages over independent mode filters although they introduce a little fundamental change in the feasibility and the limitations of ceramic filters.

5.11 In high frequency ceramic resonators having partial electrodes, with specific dimensions and mass, the vibration energy can be 'trapped' and maintained under the electrode and in the immediate surrounding. A piezoelectric mechanical filter can be realized by utilizing mutual acoustic coupling between several electrode regions. Thus a complete filter may be obtained in monolithic or integrated form.

6. BASIC FILTER CHARACTERISTICS

6.1 General Characteristics — The following is a brief summary of the characteristics of individual types of filters using passive linear elements. Some typical applications are given in **6.1.1** to **6.1.6**.

6.1.1 *I.F. Filters for Solidstate Receiver*

6.1.1.1 These filters for frequencies between 440 and 480 kHz are the most widely used production units. I.F. filters are manufactured in different circuits and designs, ranging from a simple interstage coupling circuit to a multiple section ladder type filter.

6.1.1.2 The pass bandwidth (at 6 dB) will lie between 6 and 50 kHz. The possible volume of such filters may be less than one cm^3.

6.1.1.3 An example of a filter characteristic with 6 dB at 8 kHz bandwidth and with 60 dB at 20 kHz bandwidth, with terminating impedance of 1 200 and 600 Ω is given in Fig. 4A.

6.1.1.4 The characteristics of an I.F. filter using resonators with ring and dot electrodes with varying terminations at the input and the output are given in Fig. 4B.

6.1.2 *I.F. Filters for 10·7 MHz*

6.1.2.1 An example of such filter characteristic is given in Fig. 5. The pass bandwidth shall be approximately 210 kHz.

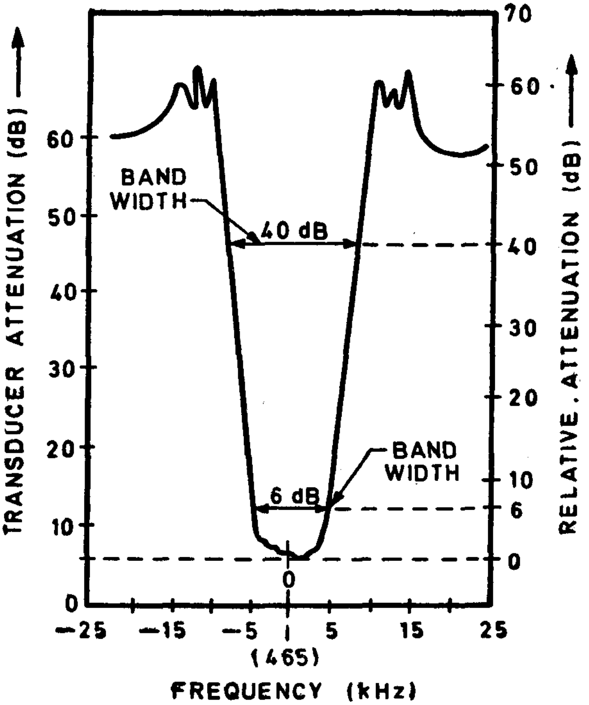
6.1.2.2 Pass bandwidth should be wide enough to pass audio signals on the carrier under conditions of varying temperature and errors in both transmitter and receiver frequencies. The permissible errors of these frequencies are normally laid down by the responsible authorities.

6.1.2.3 Stop band and transition band attenuations are determined by the position of the next channel and its frequency stability together with the frequency spectrum produced by its superimposed signal modulation. Adequacy of performance may be determined by a two-signal test which checks the interference and crosstalk on a wanted channel caused by a signal in an adjacent channel.

6.1.2.4 Typical filters are designed for operation in circuits employing solidstate devices with terminations ranging from a hundred to a few thousand ohms. It is necessary to ensure that tolerances on the terminations are not too wide, to avoid undesirable distortions of characteristics in the pass band (ripple), which may result in unacceptable distortion sensitivity to interference or both.

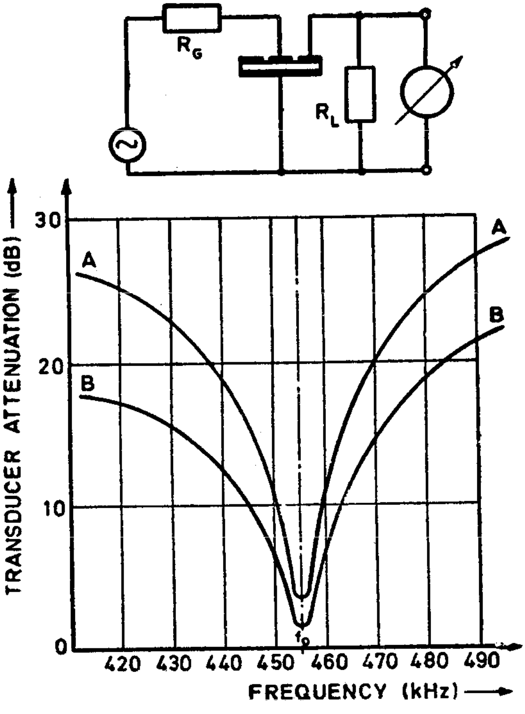
6.1.3 *I.F. Filters for 4-6 MHz* — Under consideration.

6.1.4 *Filters for Multiplex Stereo Receivers* — A number of filters ranging from 15 to 70 kHz are required in decoding multiplex stereo signals. Various ceramic filters are available for this application. Figure 6 shows typical characteristics of a ceramic filter for pilot selection.



4A Attenuation Characteristic of an I.F. Ceramic Filter of Multiple Ladder Configuration Consisting of Eight Resonators

FIG. 4 ATTENUATION CHARACTERISTIC OF I.F. FILTER — *Contd*



i) *For Curve A*

$R_G = 12\ k\ \Omega$
$R_L = 2{\cdot}2\ k\ \Omega$

ii) *For Curve B*

$R_G = 5{\cdot}6\ k\ \Omega$
$R_L = 1\ k\ \Omega$

4B Attenuation Characteristic of an I.F. Filter Having a Form of Resonator with Ring and Dot Electrodes with Various Terminating Impedances

FIG. 4 ATTENUATION CHARACTERISTIC OF I.F. FILTER

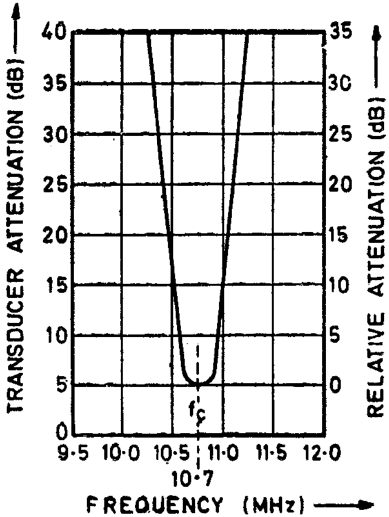


FIG. 5 ATTENUATION CHARACTERISTICS OF A CERAMIC FILTER WITH $f_c = 10·7$ MHz

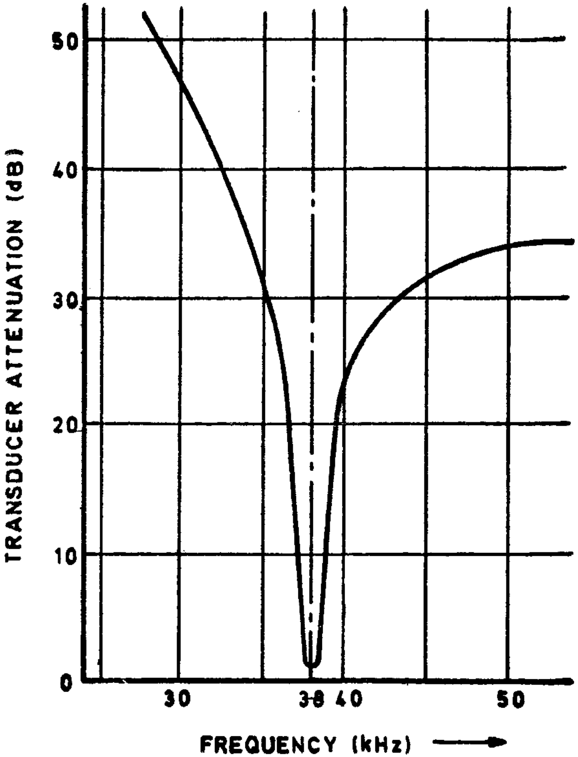


FIG. 6 ATTENUATION CHARACTERISTICS OF A TYPICAL CERAMIC FILTER FOR THE SELECTION OF THE PILOT FROM THE MULTIPLEX STEREO SIGNALS

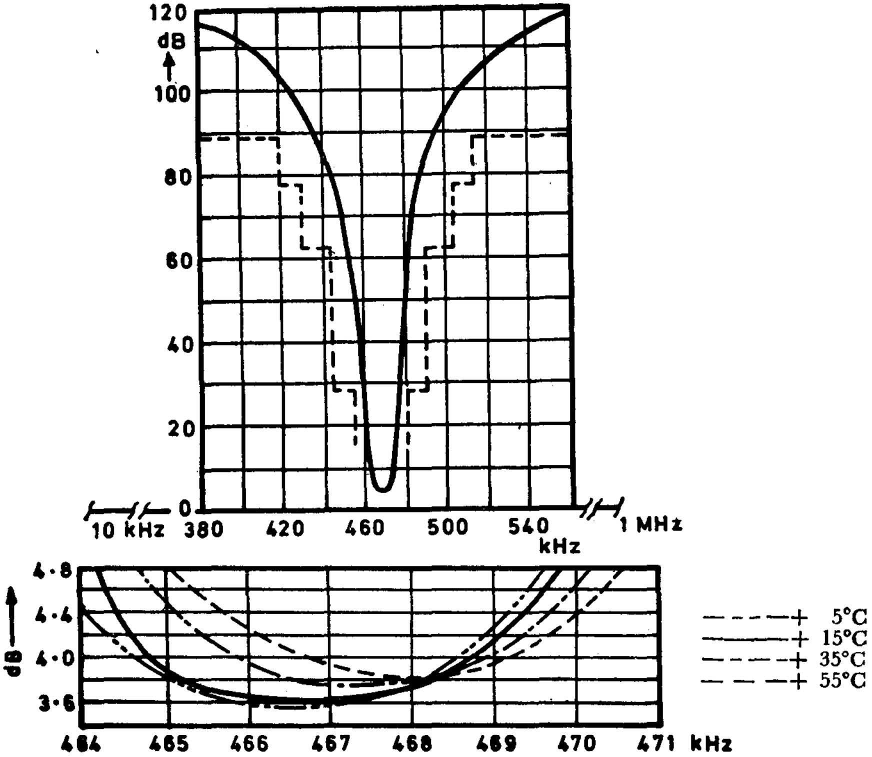
6.1.5 *Filters for Carrier and Pilot Frequencies in Carrier Telephone Systems* — In the f.d.m. (frequency divisions multiplex) carrier frequency systems, many sophisticated LC, crystal or mechanical filters are used. The present available materials do not allow for a large use in the field of carrier telephone, nevertheless some applications (for example, carrier generation, signalling generation, auxiliary frequencies), may be found for the ceramic filter. For pilot selection, very stringent specification concerning the stability around the centre frequency is imposed. For most designs, the circuit of the filter consists of input and output transformers, four resonators arranged in two Jaumaun (hybrid) sections, capacitors and resistors. The resonators are designed for maximum bandwidth, where in the filters the bandwidth is diminished by more stable (in temperature) capacitors. The attenuation reflections observed at the junction of the two Jaumaun sections (caused by the different impedances of the sections of the filter—due to the tolerance of L_1), could be minimized through resistor matching π — network of about 1 dB. Figure 7 shows typical characteristics of carrier supply filter. Figure 8 gives the frequency response characteristic of a pilot selection filter.

6.1.6 *Response Characteristics* — For filters where the form of the amplitude characteristics is important, there exist such theoretical response characteristics as the Chebyshev, maximally flat or extra-flat (Butterworth), eliptic function response, etc. Where the phase characteristic is more important, such as in digital transmission systems there exists the Gaussian function response. It is not good practice to specify a filter in terms of these characteristics because they are theoretical in nature and in practice filters can only approximate the ideal response, due to the spread between the resonator parameters, according to the real terminations, etc. It should also be noted that since there is a relationship between phase and amplitude characteristics, it is not possible to realize both characteristics independently.

6.2 Utilization and Limitations — Information on utilization and limitations is given in **6.2.1** to **6.2.4**.

6.2.1 *Effect of Bandwidth on Availability of Ceramic Band-Pass Filters*

6.2.1.1 The available parameters of ceramic resonators affect the characteristics of the filter unit and thus imposes constraints on the design of the filters. Most ceramic filters used have band-pass characteristics. Figure 9 gives the pass bandwidth of ceramic filters *versus* definite reference frequency regions. These pass bands can be made available without critically difficult development work. The values given are a guide only to what is technically possible. Commercial availability depends on such factors as quantity, environmental requirements, size, cost, etc.



Centre Frequency	Bandwidth						Insertion Loss	Maximum Attenuation
	1 dB	6 dB	25 dB	60 dB	75 dB	85 dB		
468 kHz	5 kHz	10 kHz	24 kHz	48 kHz	72 kHz	96 kHz	5 dB	85 dB
	>	<	<	<	<	<	<	

Centre Frequency

Tolerance: ± 1 kHz

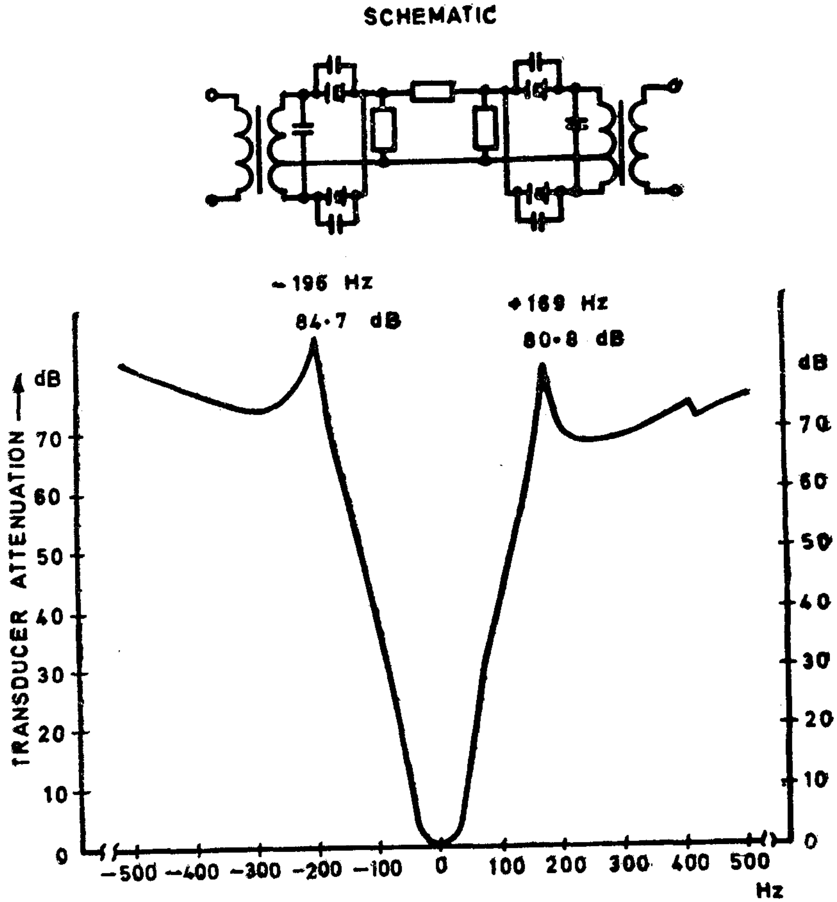
Stability : Within +0·2 percent for 5 years
Within $60 \cdot 10^{-6}$/°C (0 — 50°C)

Impedance

Input : 2 500/10·000 Ω

Output: 2 500/10·000 Ω

Fig. 7 Attenuation Characteristics of a Typical Ceramic Filter for Carrier Selection for a Telephony System



NOTE — This curve is applicable for 25°C.

FIG. 8 FREQUENCY RESPONSE CURVE OF 12·08 kHz PILOT FILTER

6.2.1.2 The following clarify the reasons on account of which in certain regions (*see* Fig. 9), there are difficulties relating to the bandwidth available at different reference frequencies:

a) *Region of Q and frequency stability problems*

   1) The minimum pass bandwidth of ceramic filters results from temperature and time stability of ceramic resonators, and from their quality factor.

   2) Filters with 0·5 percent pass bandwidth are difficult to implement, because their pass band is comparable to the relative frequency shift due to the temperature (of 0·2 percent) and ageing (of 0·2 percent) (overall instability 0·4 percent); and the Q of resonators proves insufficient to guarantee a satisfactory minimum transducer attenuation over the operating temperature range for these, having relatively narrow (for ceramic) pass band filters.

   3) The application of such filters is limited by those cases when severe requirements are not imposed on the edges of the filter pass band and the mid-band frequency stability, that is, they can be used for separation of discrete (carrier or reference frequencies).

b) *Limitations due to relative frequency spacing of ceramic resonators* — Filters with pass bandwidths greatly exceeding the upper boundaries shown in Fig. 9 may not be made available without added inductors (although in principle they are available within definite limits).

   NOTE — Since such filters are not yet widely used, they are not considered in this standard.

6.2.2 *Limitations on Temperature Performance*

6.2.2.1 Narrow band filters possess temperature characteristics which are dominated by the temperature coefficient of the resonators and the capacitors. To a first order, the effect is confined to a variation of the mid-band frequency in sympathy with the variations of resonator frequency.

6.2.2.2 Since most resonators do not have a linear temperature coefficient, measurement at a substantial number of temperatures may be necessary to obtain accurate data. For narrow bandwidths, differences in temperature characteristics of resonators within the filter may result in variations of ripple magnitude with temperature.

6.2.2.3 Variation of the equivalent resistance of a resonator with temperature will affect the minimum transducer attenuation considerably. This is important for pilot selection filters.

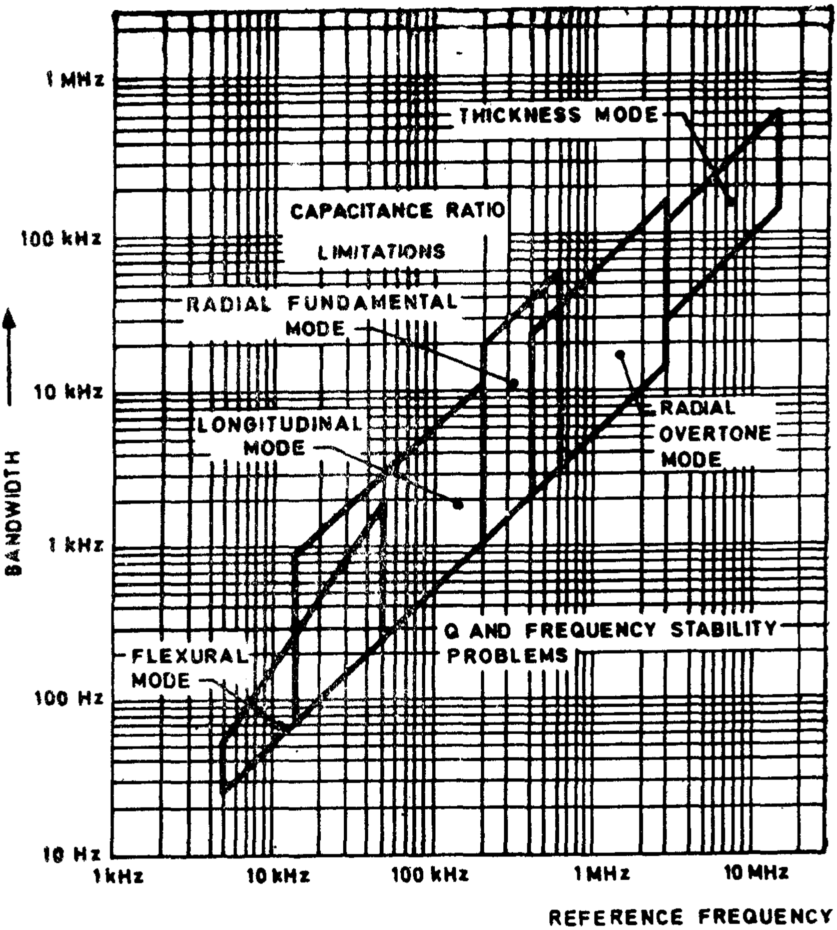


Fig. 9 Frequency Ranges of Ceramic Band-Pass Filters (Without Requiring Critically Difficult Development)

6.2.2.4 For wideband filters, the main effects will be upon pass band shape depending on the temperature coefficient of resonance and anti-resonance frequencies.

6.2.3 *Limitations on Environmental Performance*

6.2.3.1 When ceramic filters are not hermetically sealed, special consideration should be given to environmental aspects; one aspect is moisture and the second is mechanical tests.

6.2.3.2 In some cases mounting leads of resonators are rigidly connected and an excessive external stress on these leads may distort filter characteristics.

6.2.3.3 Resistance to shock and vibration tests may be a function of direction of force application. Where requirements are severe, it may be possible to optimize the filter resonator with this in mind.

6.2.4 *Standardization*

6.2.4.1 Since there are many more possible points of difference between various piezoelectric ceramic filters than between other components which do not consist of an assembly of elements, it is not possible at the present time to standardize size, shape, reference frequency and other filter characteristics.

6.2.4.2 Some degree of similarity does exist between various filters used in the first I.F. of an equipment which is at, for example, 445 or 465 kHz. However, difference may exist between products of different filter suppliers with particular reference to terminating impedances. Even then manufacturer's requirements differ for one or more of the following reasons:

a) *Application* — Some requirements specify that a filter should provide all the relative attenuation required, others provide it by means of a stage set, consisting of separate filters. For some applications, size is critical, for example, pocket sets, while for others, cost is dominant. Some applications may require different relative attenuation performance.

b) *Impedance* — In general, filters are designed to operate between specific terminating impedances.

c) *Local oscillator stability* — The pass bandwidth required of a filter will be partly determined by the local oscillator stability combined with any drift of the equipment.

6.3 Input Level — Drive level performance may be limited by reason of:

a) ceramic resonator frequency change, and

b) ceramic resonator degrading.

6.3.1 *Ceramic Resonator Frequency Change* — The maximum levels at which the filter is required to operate within limits should be stated. For narrow bandwidths this will be more important than for wider bandwidth filters due to the greater frequency stability required.

6.3.2 *Ceramic Resonator Degrading*

6.3.2.1 Distortions in filter characteristics caused by excessive level of drive may remain even after the level has returned to a normal value.

6.3.2.2 This may be a function of signal frequency and whether the filter is correctly terminated. Sensitivity to high drive levels will be highly dependent on resonance frequeney of the ceramic elements. If normal conditions are satisfactory, the implications of testing and other abnormal conditions such as the filter being open-circuited at the output terminals should be considered, since this could result in substantially greater power reaching the resonator.

6.4 **Permissible dc Voltage** — A dc voltage applied to a ceramic resonator may cause a permanent change in the polarization of ceramics and hence in the resonator characteristics. Care must be exercised when a dc voltage is applied to a ceramic filter. Even such a small voltage as produced by power supplies for solidstate devices may cause trouble.

7. PRACTICAL REMARKS

7.1 Certain precautions are required in order to obtain a satisfactory performance when the filter is inserted between external circuits, especially solidstate devices.

7.2 The following are important:

a) Both input and output terminals of a filter should be properly terminated by specified resistances. At a high frequency it is frequently required that stray capacitances are kept below specified values or sometimes are adjusted to certain specified values. Considerable distortions in the pass band due to improper terminations will be observed.

b) Stray coupling between input and output terminals should be kept to a minimum by proper grounding or shielding. Otherwise guaranteed loss in the stop band may not be realized.

8. MEASURING TECHNIQUES

8.1 The measuring techniques shall be in accordance with IS: 6133 (Part I)-1971*.

9. MARKING

9.1 Marking which shall be in line with 6 of IS : 6133 (Part I)-1971* includes type number, reference frequency and mark of origin with additional marking to be agreed upon between customer and manufacturer.

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*Specification for piezoelectric filters for use in telecommunication and measuring equipment: Part I General requirements and tests.

10. SPECIFICATION PROCEDURE

10.1 When the requirements are to be met by a standard item, it will be sufficient to specify the corresponding article sheet.

10.2 When the requirements cannot wholly be met by an existing article sheet, the article sheet should be quoted together with known differences.

10.3 In the case where the differences are such that it is not reasonable to quote an existing article sheet, a new sheet is to be prepared in a similar form to that already used for standard article sheets.

10.4 A suitable check list (*see* Appendix A) will be useful for ordering a piezoelectric ceramic filter and should be considered in drawing up a specification.

10.5 In an unsymmetrical filter, it is recommended that stop band and pass band requirements be specified with reference to precise frequencies rather than to quote bandwidths in both regions.

10.6 It should be clearly stated in the specification whether the filter is required to operate whilst under conditions of shock, vibration or acceleration. If it is, the possibility of noise generation and its acceptable limit should also be considered. This is important for lower frequency filters only.

APPENDIX A

(*Clause* 10.4)

CHECK LIST FOR ORDERING PIEZOELECTRIC CERAMIC CRYSTAL FILTERS

A-1. APPLICATION

(For example, for stationary, portable or aircraft equipment, etc)

A-2. DESCRIPTION

(Desired volume or outline)

A-3. MANDATORY REQUIREMENTS

A-3.1 Electrical

a) *Reference Frequency*

b) *Pass-Bandwidth Characteristics*

  1) Bandwidth (at ... dB),

  2) Maximum ripple,

  - 3) Maximum transducer attenuation,
  - 4) Shape factor (at ... dB and ... dB),
  - 5) Minimum relative attenuation within stop-band (from ... Hz to ... Hz), and
  - 6) Magnitude and nature of input and output terminating impedances.

A-3.2 Environmental

- a) *Temperature Range*
  - 1) Operating,
  - 2) Operable, and
  - 3) Storage.

A-4. OPERATIONAL REQUIREMENTS

A-4.1 Electrical

- a) Unwanted responses,
- b) Maximum level,
- c) Input level,
- d) Insulation resistance,
- e) Ageing, and
- f) Other requirements (for example, phase characteristics).

A-4.2 Environmental Requirements

- a) *Climatic*
  - 1) Humidity
  - 2) Others (for example, sealing, temperature cycling)
- b) *Mechanical*
  - 1) Bump,
  - 2) Shock,
  - 3) Vibration, and
  - 4) Acceleration.

A-4.3 Physical Requirements

- a) Type number of ISI standard filter outline (if any),
- b) Length,
- c) Width,

- d) Height,
- e) Terminals and mounting accessories,
- f) Markings,
- g) Weight, and
- h) Others (for example, solderability, etc).

A-5. INSPECTION REQUIREMENTS

- a) Related specifications,
- b) Inspection authority,
- c) Acceptable quality levels,
- d) Type tests, and
- e) Others.

NOTE — It is also necessary to include the severity of the testing required, that is how often the test shall be performed, the percentage to be tested and the acceptable failure rate.

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